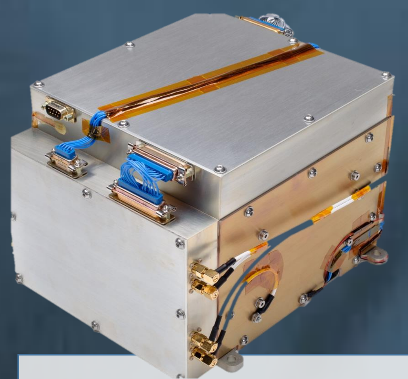

UV-LED

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Overview

UV-LED is a small satellite technology demonstration payload being flown on the Saudisat-4 spacecraft that is demonstrating non-contacting charge control of an isolated or floating mass using new solid-state ultra-violet light emitting diodes (UV-LEDs). Integrated to the rest of the spacecraft and launched on a Dnepr in June 19, 2014, the project is a collaboration between the NASA Ames Research Center (ARC), Stanford University, and King Abdulaziz City for Science and Technology (KACST). Beginning with its commissioning in December, 2015, the data collected by UV-LED have validated a novel method of charge control that will improve the performance of drag-free spacecraft allowing for concurrent science collection during charge management operations as well as reduce the mass, power and volume required while increasing lifetime and reliability of a charge management subsystem. UV-LED continues to operate, exploring new concepts in non-contacting charge control and collecting data crucial to understanding the lifetime of ultra-violet light emitting diodes in space. These improvements are crucial to the success of ground breaking missions such as LISA and BBO, and demonstrate the ability of low cost small satellite missions to provide technological advances that far exceed mission cost.

New Technology

To control electrostatic charge build up on an isolated proof mass, power hungry and heavy mercury vapor lamps are commonly used. However, UV-LED utilizes new innovative deep UV Light Emission Diodes (LED) as an alternate light source to replace mercury lamps. Compared to mercury lamps, these UV-LEDs offer significant advantages of small size, long lifetime, light weight, and fiber-coupled operation, with very low power consumption. Additionally, the emission from the UV-LEDs can be modulated at frequencies of 100 Hz or more (current Hg discharge lamps cannot be modulated and must operate at zero frequency), allowing charge control to operate at frequencies that would not affect the science operations of a mission (typically 10^{-4} Hz to 10 Hz).

Figure 1. To-39 LEDs

Figure 2. Surface Mount LEDs

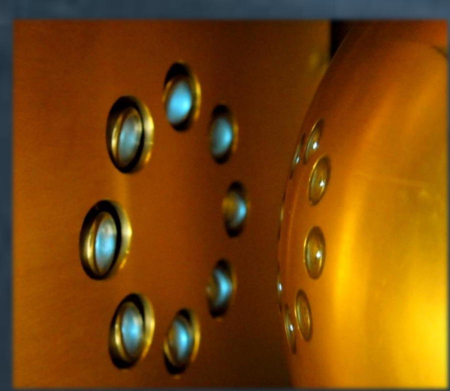

Figure 3. UV-LEDs powered on, illuminating light on proof mass

UV-LED Technology Demonstration

1. Space qualify UV light emitting diode (TRL8)
   - Measure performance and monitor any degradation over lifetime of mission operations
   - Measure electrical voltage-current (V-I) characteristics
   - Measure voltage-current-optical power (V-I-P) characteristics
2. Demonstrate non-contacting AC charge management in space (TRL7)

UV-LED Test Data

Thorough in lab performance testing of the UV-LED instrument was conducted at the component and system level to:

- Characterize and monitor the performance of the UV light emitting diodes by measuring V-I and V-I-P characteristics
- Demonstrate AC Charge Control
- Validate and qualify the instrument for flight through environmental tests (Random Vibration, Shock, TVAC, Functional and Software)
- Validate the Spacecraft/Instrument interface through
  - TVAC and Random Vibration
  - Communication interface tests through Spacecraft and ground systems

Instrument Description

- Size 230x270x185mm (w x h x l)
- Mass 6.3kg
- Average Power 9.5W
- 2 identical separate experiments:
  - 8 UV-LEDs package
  - 4 bias plates (common to both experiments)
  - 1 power electronics and communications box

Figure 4. Interior of UV-LED, showing gold-coated proof mass and 2UV-LED boxes on either side

LED & Photodiode Performance Tests

- Selected different UV-LED packages based on:
  - V-I and V-I-P measured
  - Environmental testing
- Measured and characterized performance:
  - Pre/post enclosure in housing (Figures 1 & 2)
  - Optimal operating temperature
- Monitored performance by measuring V-I and V-I-P characteristics during instrument flatsat, pre/during/post instrument integration & environmental tests, and pre/during/post instrument to spacecraft I&T.
  - LEDs: Drive LEDs with a commanded current from 0-10mA, measure electrical voltage-current (V-I) of different LED packages (Figures 5 & 6)
  - Photodiodes: Drive LEDs with a commanded current from 0-10mA, measure voltage-current-optical power (V-I-P, Figures 7 & 8)
- Demonstrated UV-LED charge control post instrument integration

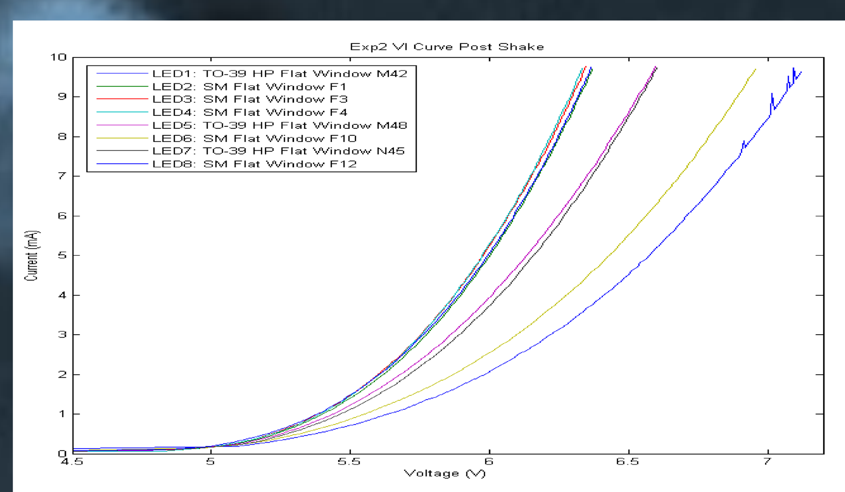

Figure 5. VI plot of SM and TO-39 (Experiment 2) post system level (SC/instrument) random vibration testing

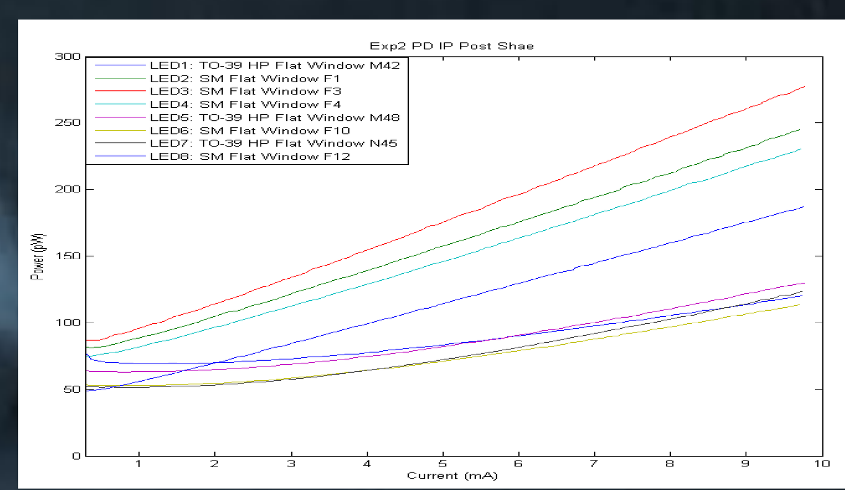

Figure 6. IP plot of SM and TO-39 (Experiment 2), post instrument level random vibration

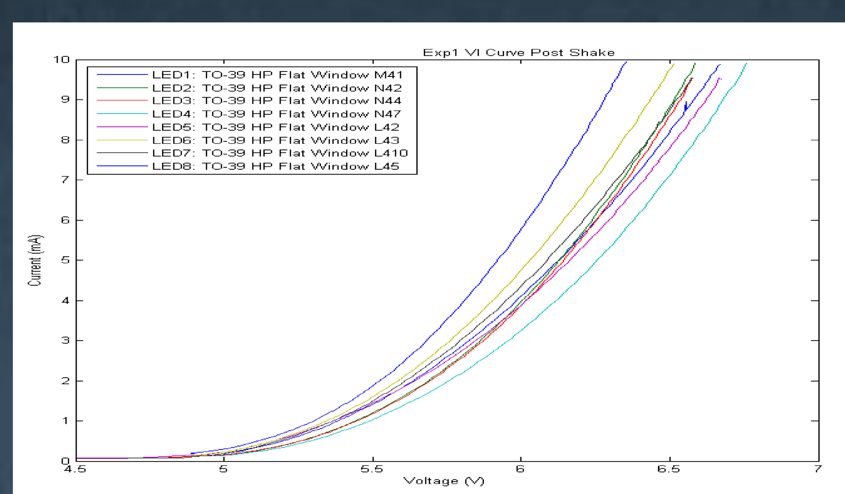

Figure 7. VI plot of TO-39 (Experiment 1), post instrument level random vibration test

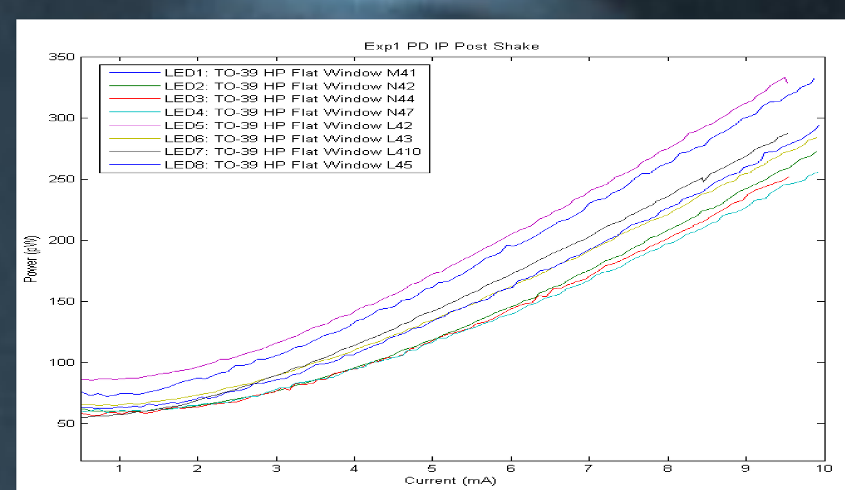

Figure 8. IP plot of TO-39 (Experiment 1), post instrument level random vibration test

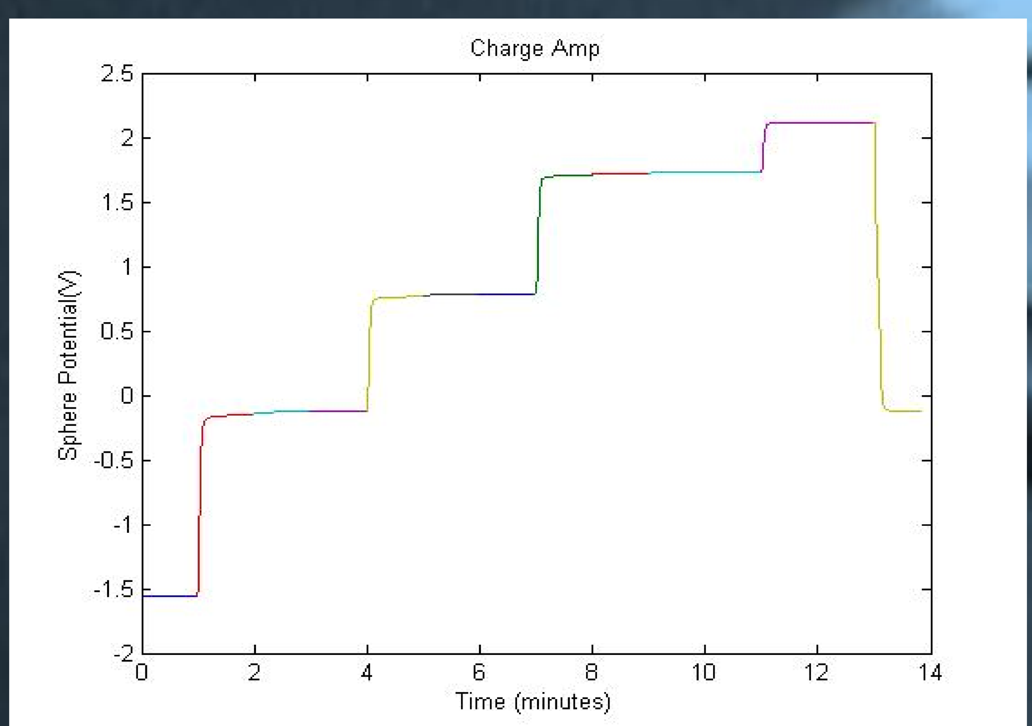

Figure 9. Proof mass potential decrease. EM.exp2, post instrument I&T

Charge Control

- UV-LED controls the buildup of charge by creating a cloud of electrons between the proof mass and the bias plates surrounding it. The electrons are created by illuminating the proof mass and bias plates with ultra-violet light (~255 nm) from the LEDs, causing the release of electrons via the photoelectric effect. By changing the potential of one or more bias plates, the electrons can be made to flow from or to the proof mass, thereby controlling its charge.
- Demonstrated charge transfer by measuring a proof mass potential increase when UV-LEDs and AC bias voltage are in phase (0° phase shift) (Figure 9), and measured a proof mass potential decrease when UV-LEDs and bias plates are out of phase (180° phase shift) (Figure 10)

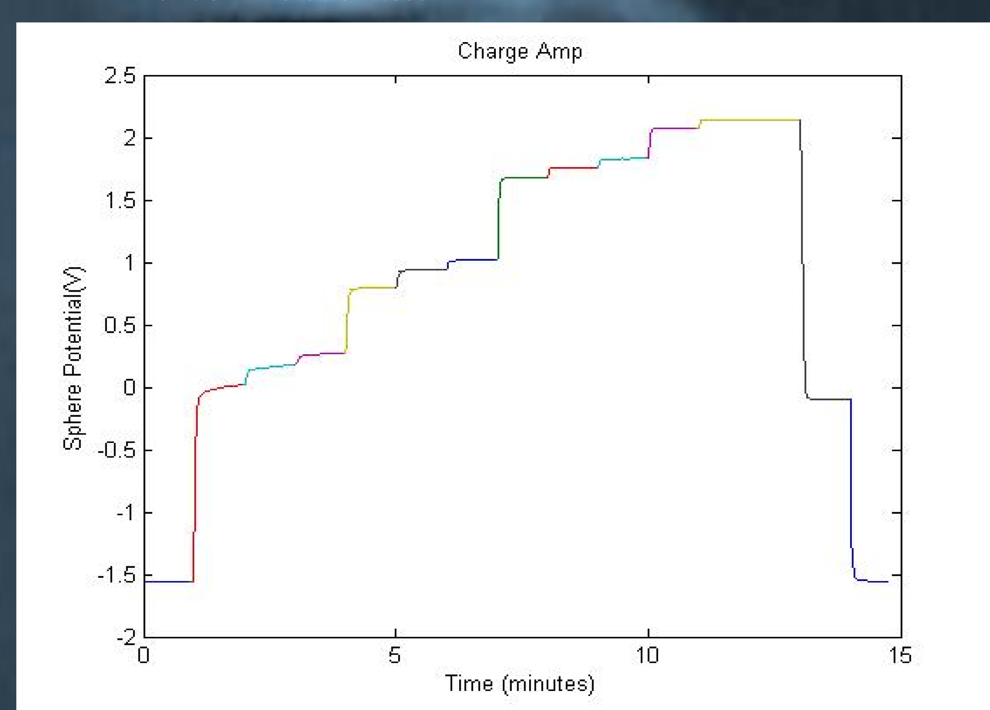

Figure 10. Proof mass potential increase. EM.exp2, post instrument I&T.

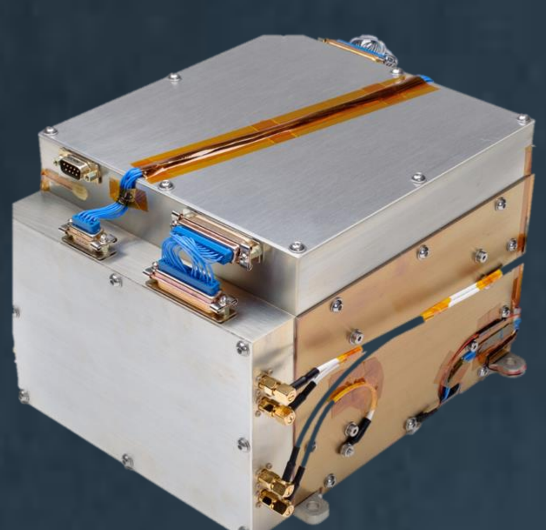

Figure 11. UV-LED Flight Payload

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UV-LED Mission Operations

- Extensive characterization and experimentation (December, 2014 to present)
- Instrument operated the same way it has been operated and tested in lab
- UV-LED's performance monitored for remainder of SaudiSat4 mission (1 day per month)

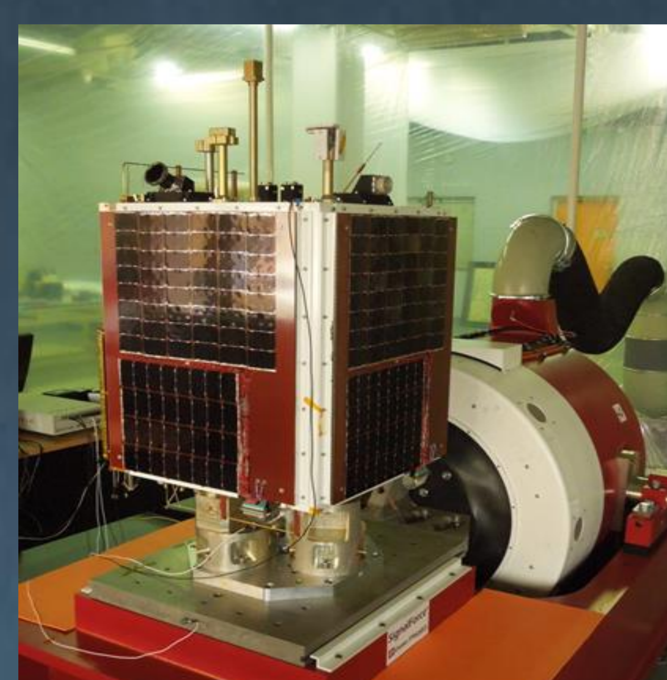

Figure 12. Saudi-Sat4 and UV-LED integrated, on shake table post random vibration